Better Plants
U.S. DEPARTMENT OF ENERGY

Getting Started with Water Efficiency at Manufacturing Facilities

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Agenda

- Overview of Department of Energy’s (DOE) Better Buildings, Better Plants program
- Introduction to water management
- Setting and tracking water intensity targets
- Example of tracking water intensity targets
- Water efficiency measures
- System Dives
  - Pumping
  - Cooling towers
  - Steam
- Other tools and resources

Better Buildings, Better Plants

- Through Better Plants:
  - Partners set long-term efficiency goals (25% energy intensity over 10 years)
  - Receive technical assistance and national recognition for their leadership

- Manufacturers have two opportunities to engage in Better Plants:
  1. Broader-based *Program* level
  2. Higher-level *Challenge*

Productivity. Cost Savings. Competitiveness.

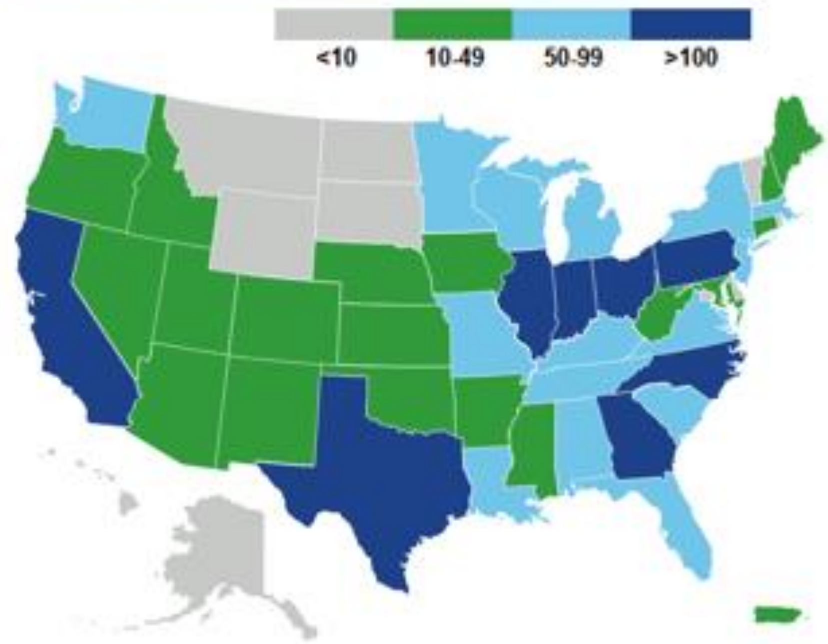
Better Plants Overview

Energy savings and program footprint continue to grow

Better Plants Snapshot

Accomplishments	Total
Number of Partners	190
Approximate Number of Plants	2,600
Percent of U.S. Manufacturing Energy Footprint	11.5%
Reported Savings	
Cumulative Energy Savings (TBtu)	600
Cumulative Cost Savings (Billions)	$3.1
Cumulative Avoided CO_2 Emissions (Million Metric Ton)	34.7
Average Annual Energy Intensity Improvement Rate	3.0%

Regional Distribution of Better Plants Facilities



33 new partners, 10 goal achievers in 2016.

Better Plants Challenge

Simplot
Bringing Earth's Resources to Life
3M
CFMartin&Co. EST. 1833
United Technologies
Schneider Electric
LA DWP
BRIGGS & STRATTON
Cummins
VOLVO
NEW Water
The brand of the Green Bay Metropolitan Sewerage District
GM
Johnson Controls
IR Ingersoll Rand
Electrolux
Ford
NISSAN
GENERAL MILLS
VVWRA
LENNOX INTERNATIONAL
EASTMAN
HARBEC
BD
OWASA
Holcim
BENTLEY
BCW&SA
GE
TOYOTA
Encina Wastewater Authority
City of Ithaca, N.Y. Incorporated 1888
TE connectivity
DARIGOLD
SAINT-GOBAIN
legrand®
TOWN OF BATH, NY
Environmental Services
ALCOA
Celanese
The chemistry inside innovation™

Technical Support: Technical Account Manager (TAM)

- Help with energy baselines and data tracking/reporting
  - **Corporate-Level** Approach
  - **Facility-Level** Approach
  - **Regression-Based** Approach
- TAMs facilitate access to all other DOE resources
- TAMs help partners develop a roadmap for achieving their goal(s)

Technical Assistance: In Plant Trainings

Existing Training Topics:

- Compressed Air
- Pumping
- Steam
- Process heating
- Fans
- Energy Treasure Hunt Exchanges
- **EE in Water/Wastewater Treatment**
- Industrial Refrigeration
- Strategic Energy Management

- Teach participants how to conduct assessments, use DOE tools, and implement projects
- Open to employees from host plant, peer companies, suppliers
- ~70 INPLTs, 850 participants since 2011
- Identified > 3 TBTU and $14 million in energy savings between 2011 and 2015
- Pre-INPLT webinars available on program website

Supply Chain Initiative

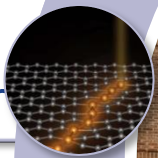
- 4 Better Plants partners are working with 30 suppliers to set energy-saving goals and track progress
- Suppliers receive DOE technical support, including priority access to free energy audits

Legrand	UTC	Lockheed Martin	Honda NA
Chapco	GKN Aerospace	Cascade Engineering Technologies, Inc.	KYB Americas
Coilplus	Hitchiner	Clearwater Engineering, Inc.	Newman Technologies
Complete Design & Packaging	MB Aerospace	Cooperative Industries Aerospace & Defense	Asama Coldwater Manufacturing
Durex	RTI International Metals, Inc.	The Harva Company, Inc.	American Mitsuba
Lynam	Selmet, Inc.	Research Electro-Optics	NSK Americas
Magnetic Metals	Weber Metals, Inc.	Savage Precision Fabrication	Mahle Engine Components
Rowley Spring & Stamping	Jedco, Inc.	Vanguard Space Technologies	Cardington Yutaka
Stanley Spring & Stamping		Tri-State Plastics, Inc.	

New Initiative: Technology Transfer

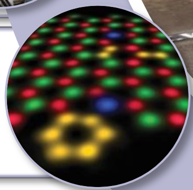
Leveraging ORNL assets

Neutron scattering: SNS and HFIR
- World's most intense pulsed neutron beams



Leadership-class computing: Titan
- Nation's most powerful open science supercomputer

Carbon fiber manufacturing
- Open-access carbon fiber process development facility



Advanced materials
- DOE lead lab for basic to applied materials R&D

Science and technology park
- Co-location for industry collaboration

Diagnostic Equipment Loan Program

Helping Better Plants Partners measure operating data to evaluate equipment performance and quantify energy performance improvement

- Free of charge, including shipping
- Use equipment for one day, or up to four weeks
- Limited technical assistance to help w/ selection and use of tools
- First come, first serve application

Better Buildings Summit

BETTER BUILDINGS
SUMMIT

SAVE THE DATE

WASHINGTON, D.C.
MAY 15-17, 2017

Join 900+ Better Buildings Partners and Allies

- **EXPLORE AND SHARE**
  innovative strategies, emerging trends, and high-impact technologies in energy and water efficiency
- **CONTRIBUTE**
  to interactive sessions focused on industry-specific and proven solutions to help you take on what's next
- **PARTICIPATE**
  in showcase building tours, financial ally speed dating, ask-an-expert meetings, peer-to-peer networking
- **LEVERAGE**
  your organization's commitment to sustainability

Register early - space is limited
REGISTRATION OPENS JANUARY 2017

FOR MORE INFORMATION AND TO REGISTER:
betterbuildingsinitiative.energy.gov/summit

@BetterBldgsDOE #BBSummit2017

Better Buildings Solution Center

- Nearly 200 industrial solutions tested and proven by Partners – 100 added in 2016
- Find solutions by topic, building type, solution type, building size, sector, technology, location, and more.

energy.gov/bbsc

Introduction to Water Management

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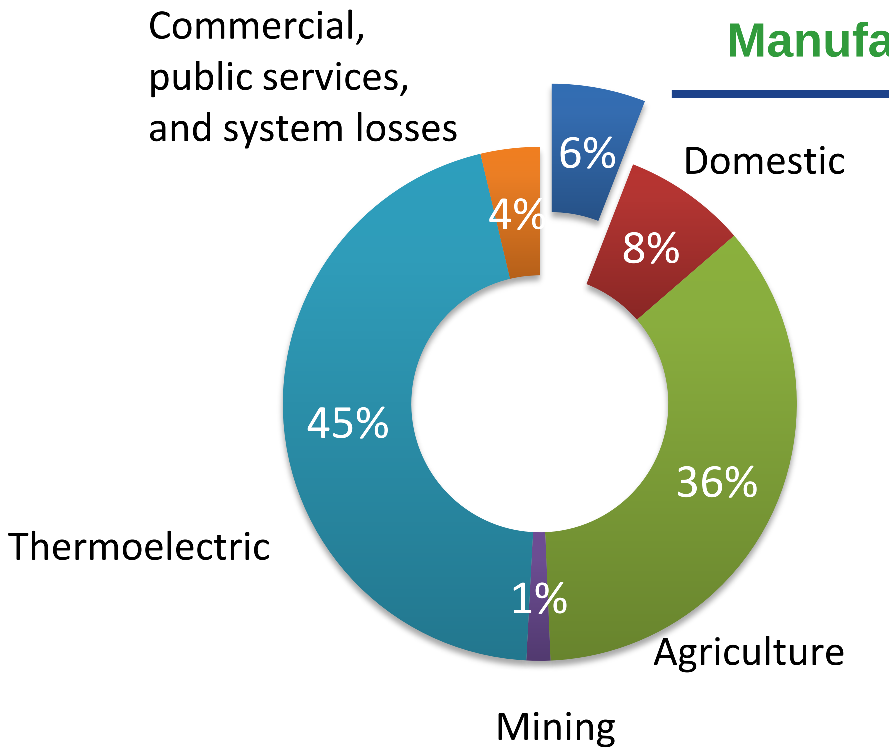
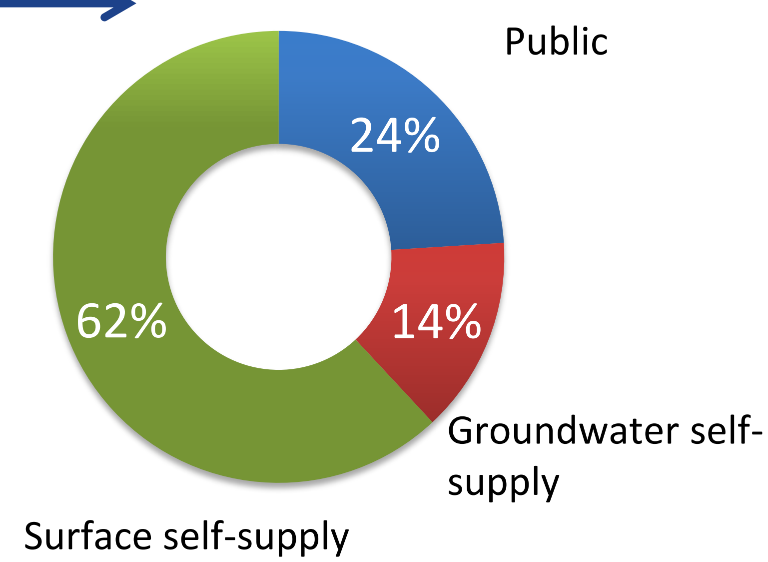
Background on U.S. manufacturing water use



Estimated 2010 water use (fresh and saline) by end use sector. Figure adapted from Maupin 2014



Estimated sources of manufacturing water use (fresh and saline).

- 94% freshwater, 6% saline
- 15% “consumptive” (from 1995 USGS)

Industrial water management

Benefits

- Operational resiliency
  - 2015 CDP Water Report: Respondents from the Industrial and Consumer Staples sectors ranked the US as a top country for facilities at risk of water related issues
- Allows for growth and planning
- Cost savings
  - Not just water, but energy, chemicals, regulatory costs too
- Improved public image
- Helps EE program

Challenges

- Resources and technical assistance not widely available* for manufacturers
- Water efficiency and management principles are less developed and promoted than energy efficiency and management principles
  - Less financial incentive to invest and/or reduce
  - But plenty of other drivers: regulation, business risk, community access,
- Lack of data

*Better Plants offers TA on water

DOE Better Buildings, Better Plants Water Savings Initiative

- DOE is working with 38 Better Buildings Challenge Partners in this effort
- Format of initiative similar to Better Plants Challenge:
  - Set water savings goals
  - Track progress
  - Publicly share success
- 9 Better Plants Partners participating

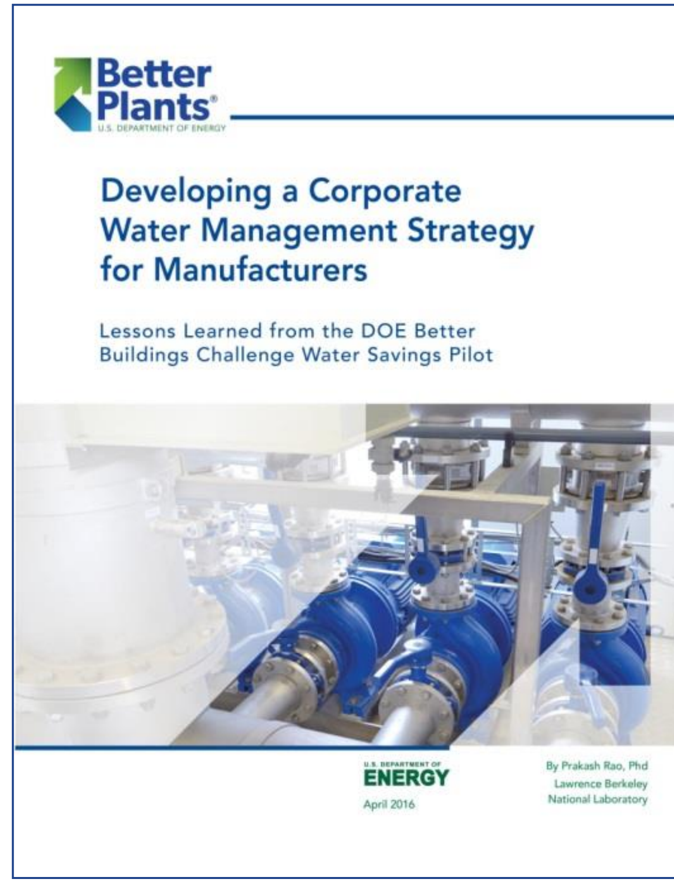
Company	Baseline Year	Total Improvement (through 2015)
★***Cummins***	***2010***	***45%***
Ford	2009	44%
GM	2010	19%
HARBEC^{+}	-	49%
Nissan	2013	13%
Saint-Gobain	2012	Pending
Toyota	2014	Pending
★ ***UTC***	***2006***	***43%***
BD	TBD	-

$^{+}$Set goal to be water neutral

★2016 goal achiever

Sharing Observed Corporate Water Management Strategies

- 7 Pilot partners shared their water management strategies with DOE
- Topics addressed include:
  - Making the business case for water saving projects
  - Facilities and water sources on which to focus initial efforts
  - Establishing baselines and targets
  - Water efficiency measures implemented



Available at: https://betterbuildingssolutioncenter.energy.gov/resources/corporate-water-management-strategy-manufacturers

Setting and tracking water intensity targets

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Why companies set targets

- One company stated not implementing water saving actions until they set a target
- Other reasons:

Driver	# of pilot partners applicable to (out of 7 in the pilot)
Regulation of water consumption and use	2
Overall cost of water	3
Energy benefits from water reduction	5
Availability of suitable water supplies	4
Risk associated with lack of access to water	4
Environmental stewardship/corporate sustainability	7
Other	3

"Other" included costs and risks associated with wastewater and business continuity

Developing targets

- SMART (Specific Measurable Achievable Reasonable Timely) targets
- Metrics and targets influenced by corporate
  - UTC – adopted corporate target
  - Cummins – target represents U.S. contribution towards global target
  - Nissan – corporate-provided target used as a minimum

Partner	% Reduction	Metric	Achievement Year	Baseline Year
BD	20%	TBD	TBD	TBD
Cummins	40%	Gallons/labor hour	2020	2010
Ford	30%	m^3/vehicle	2015	2009
GM	20%	Gallons/vehicle	2020	2010
HARBEC	Water neutral	N/A	2015	2013
Nissan	2%	Gallons/unit	2016	2013
Saint-Gobain	6%	Gallons/ton produced	2016	2012
Toyota	20%	Gallons/vehicle	2026	2014
UTC	25%	Volume	2020	2015

Developing metrics

- Mix of intensity and absolute observed
  - Intensity metrics better for tracking efficiency
  - Absolute metrics may be more appropriate in water scarce areas
  - HARBEC employed a "water neutral" target
- Some companies do both
  - Cummins, Ford, and Nissan employed intensity-based metrics for reporting, but tracked absolute internally

Outline of steps for tracking water target

- Step 1: Define the boundary
- Step 2: Choose a baseline year
- Step 3: Identify relevant variables and/or denominator for water intensity
- Step 4: Gather data on water use and relevant variable
- Step 5: Calculate water intensity
- Step 6: Calculate change in water intensity

First time through, may need to review data to pick metric for a SMART target

Step 1: Define the boundary

- Water sources and facilities whose water use is being tracked
- Include all water sources
  - More comprehensive monitoring of water use
  - Creates stronger connection to other sustainability efforts
    - E.g., unbilled water sources will still require energy to pump
  - Measurement of non-municipal water may require application of estimation techniques (see following slides)
- Fresh:
  - Municipal – purchased freshwater
  - Onsite surface – fresh water pulled in from an onsite lake, river, creek, stream, or reservoir
  - Onsite ground – fresh water pumped from the facilities groundwater sources
- Non-fresh:
  - Seawater (usually not applicable)
  - Recycled/reclaimed water - water from an external source that has been used for elsewhere, treated as required, and supplied to the facility for use
  - Rain/storm water

Step 1: Define the boundary, cont.

- If tracking across multiple facilities, including all:
  - Enables consideration of water use in strategic planning
  - Facilitates sharing of best practices across all facilities
  - Better prepares for unforeseen water issues
- Only consider facilities which you have direct financial or operational control over

Step 2: Choose a baseline year

- The year against which improvement will be measured
- Select a baseline that best represents your current operations
- Commonly aligns with:
  - Data availability
  - Broader sustainability efforts
  - Corporate initiatives
- Seek to establish a baseline spanning a full year
- Seek to establish a baseline that is no more than 3 years prior to the current year

Step 3: Identify relevant variables/water intensity denominator

- Identify metrics that may impact water use by considering how water is used at the facility
  - Production - water is used for production processes
  - Employees – water is used for domestic purposes
  - Weather – water is used for facility heating/cooling
- Water use may be driven by more than one variable
- Initially may need to test several before finalizing list

Step 4: Gather water use and relevant variable data

- Gather data for the baseline and each successive year
- Ensure that all data is tracked at the same frequency (i.e., monthly)
  - May need to apportion water bills
- First iteration, may need to collect more relevant variable info than will be ultimately used
- Use a spreadsheet or other electronic, shareable format for storing data

Where to get data

Water

- Direct measurement
  - Water bills
  - On site meters
- Estimates
  - Pump specs
  - Equipment specs

Relevant Variable

- Production
  - Financial department
  - Inventory/shipment records
  - Production schedules
  - Orders
- Weather
  - Government websites (National Oceanic and Atmospheric Administration)

Step 5: Calculate water intensity

Water intensity approach

- Creates ratio metric of water use to a single other variable
  - Production typically best
- Accounts for changes in water use associated with changes in production (or other physical unit)
- May need to create standard units
- Improvement is based on change in metric

Regression-based approach

- Adjusts water use in one period to another under consistent conditions
- Better isolates water efficiency improvements
- Can account for multiple metrics impacting water use
- Requires statistical modelling
  - DOE EnPI tool facilitates this
- Improvement is based on actual water use compared to predicted water use
- For more guidance, see DOE Energy Intensity Baselining and Tracking Guidance Document

Step 6: Calculate change in water intensity

- Calculate percent change against the selected baseline:
  - Water-Intensity Approach: Compare ratio in current year to baseline year
  - Regression-based Approach: Use model to predict water use in period of interest (current year) to baseline year
- Result is a % improvement
  - Water intensity Approach: represents improvement in water use productivity
  - Regression-based Approach: represents avoided water use

Example of tracking water intensity targets

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Example of water intensity tracking

A metal fabrication company, Smith's Stampers, has committed to a city-wide goal to reduce their water intensity by 20% by 2020. They are now beginning to track their progress.

Image on left taken from https://www.flickr.com/photos/sbeebe/14545838896, right modified from ClipartFest.

Steps 1 and 2: Boundaries and baselines

- Step 1: Define the boundary
  - Smith’s uses municipal water and self-supplied groundwater
  - Although they do not meter their groundwater usage, they recognize their use of it impacts the local community
  - Smith’s includes both in boundary
- Step 2: Select a baseline year
  - Smith’s changed a major product line in 2015.
  - 2016 represents their current situation
  - Smith’s selects 2016 as its baseline year

Step 3: Identifying relevant variables

- Facility management meet to understand what might drive water use:
  - Production – water is used for rinsing and cooling parts
  - Employees – water is used by employees for domestic purposes and number of employees and shifts tracks productivity
  - Weather – water-cooled central chilling plant provides facility space conditioning
- Management decides to track all three and make decision after reviewing data

Step 4: Gather Data on Water Use

- Smith's reviews its water bills from 2016 to determine municipal water
  - Water is billed quarterly, so they divide each bill by three months to estimate monthly water use
- Smith's does not know how much water it pulls from the ground and must estimate. Options include:
  - Field measurement
  - Estimating based on pressure head*
  - Estimating based on power consumption
- Each estimation technique has its pros and cons

*Pressure head – the pressure difference between the suction and inlet of the pump in order to achieve the desired flow rate and pressure throughout the system. Also known as "static head", it accounts for frictional and hydrostatic pressure

Pros and Cons of water use estimation techniques

Approach	Pro	Con
Field Measurement – non invasive/contact	• Does not require pump curve • Direct measurement	• Requires acquisition of an ultrasonic flow meter • Readings may not be accurate if meter not installed correctly
Field measurement - inline	• One-time set-up • Does not require pump curve	• Intrusive
Pressure head	• Straightforward	• Requires pump curve • Requires pressure measurement
Power consumption	• Straightforward	• Requires pump curve • Requires assumptions about system efficiency, operating hours, load factor, and power factor

Ultrasonic flow meters

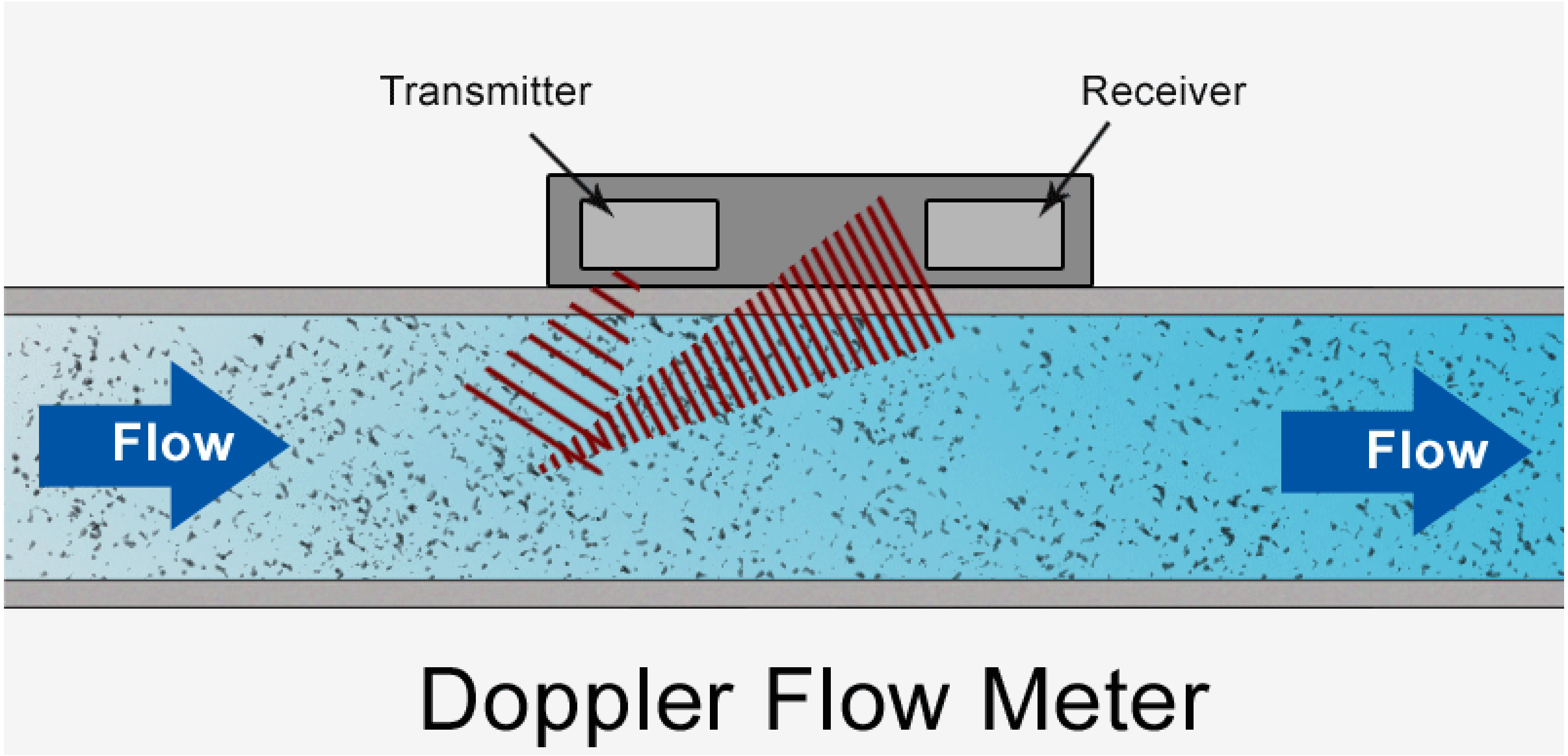


Image taken from Nick, B. Mass flow measurement techniques across the spectrum. Accessed at http://www.alicat.com/alicat-blog/mass-flow-measurement-techniques-radar/. Date accessed: April 28, 2017.

Measuring flow using pump curve

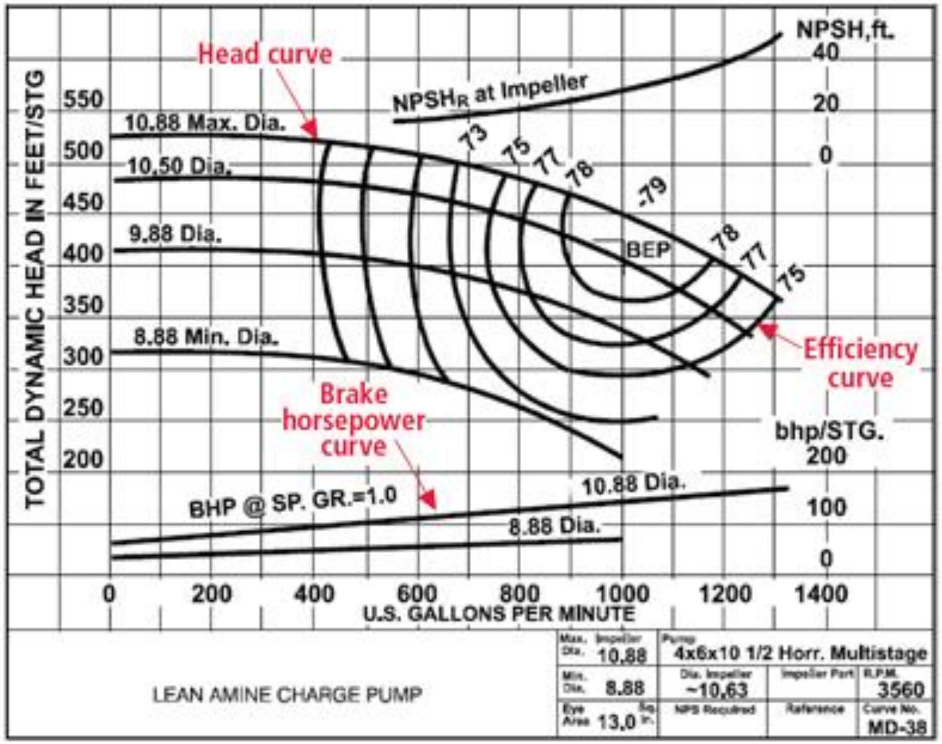


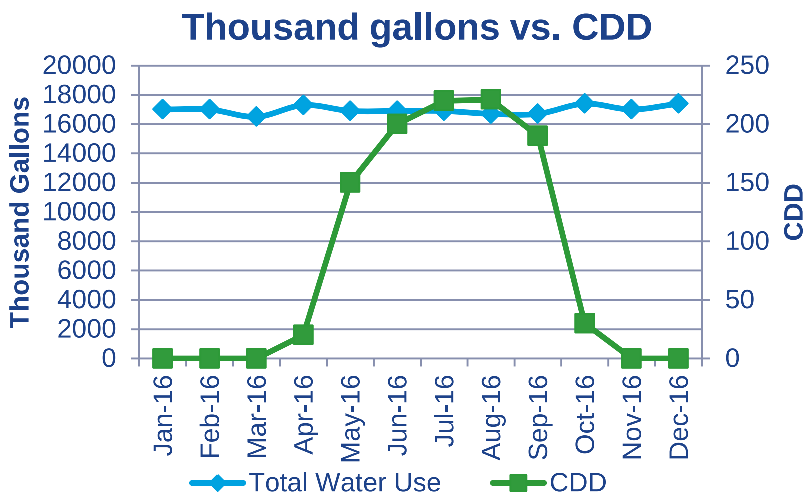
Image taken from Al-Khalifah, M., G. McMillan. 2013. Control valve versus variable-speed drive for flow control. Accessed at: https://www.isa.org/standards-publications/isa-publications/intech-magazine/2013/august/special-section-control-valve-versus-variable-speed-drive-for-flow-control/. Date Accessed: April 28, 2017.

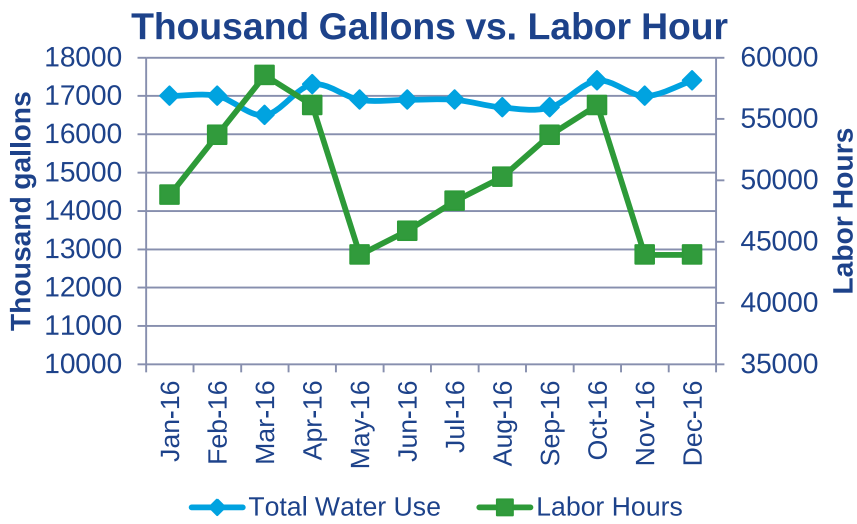
- Using head method:
  - Measure differential pressure across suction and inlet ends
  - Convert reading to units on pump curve (e.g., 2.31 feet/psi)
- Using power method
  - Measure current and volts for pump system (at control panel)
  - $BHP = \left(\frac{\sqrt{3} \times V \times I \times PF}{1000}\right) \times System\ Efficiency$
  - Look up flow rate at the power consumption

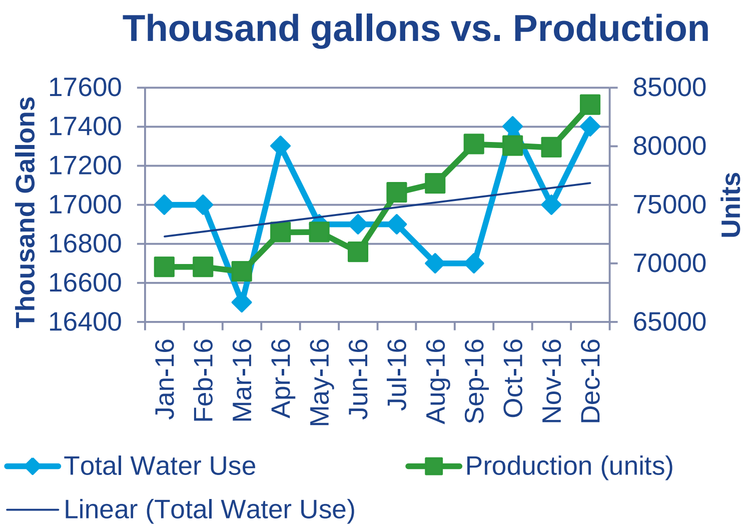
Step 4: Gathering data

	Water Use (Thousand Gallons)			Relevant Variables		
	Municipal	Groundwater	Total	CDD	Labor Hours	Production (units)
Jan-16	12100	4900	17000	0	48800	69700
Feb-16	11900	5100	17000	0	53680	69700
Mar-16	11500	5000	16500	0	58560	69300
Apr-16	12500	4800	17300	20	56120	72660
May-16	12200	4700	16900	150	43920	72670
Jun-16	12300	4600	16900	200	45872	70980
Jul-16	12400	4500	16900	220	48312	76050
Aug-16	12100	4600	16700	221	50264	76820
Sep-16	11900	4800	16700	190	53680	80160
Oct-16	12500	4900	17400	30	56120	80040
Nov-16	12000	5000	17000	0	43920	79900
Dec-16	12200	5200	17400	0	43920	83520

Review data and pick metric







- Production and total water use are best related
- Smith's selects production as its water intensity metric

Step 5: Calculate Water Intensity

	Water Use (Thousand Gallons)			Relevant Variables			Water Intensity		
	Municipal	Ground-water	Total	CDD	Labor Hours	Production (units)	Total Water Use/CDD	Total Water Use/Labor Hours	Total Water Use/Production
16-Jan	12100	4900	17000	0	48800	69700	0	0.35	0.24
16-Feb	11900	5100	17000	0	53680	69700	0	0.32	0.24
16-Mar	11500	5000	16500	0	58560	69300	0	0.28	0.24
16-Apr	12500	4800	17300	20	56120	72660	865	0.31	0.24
16-May	12200	4700	16900	150	43920	72670	113	0.38	0.23
16-Jun	12300	4600	16900	200	45872	70980	85	0.37	0.24
16-Jul	12400	4500	16900	220	48312	76050	77	0.35	0.22
16-Aug	12100	4600	16700	221	50264	76820	76	0.33	0.22
16-Sep	11900	4800	16700	190	53680	80160	88	0.31	0.21
16-Oct	12500	4900	17400	30	56120	80040	580	0.31	0.22
16-Nov	12000	5000	17000	0	43920	79900	0	0.39	0.21
16-Dec	12200	5200	17400	0	43920	83520	0	0.40	0.21
Total	145600	58100	203700	1031	603168	901500	198	0.34	0.23

Total Water Use ÷ Production = Water Intensity

Step 6: Calculate change in water intensity (after baseline year)

$$= \frac{Water\ Intensity\ in\ 2016 - Water\ Intensity\ in\ 2017}{Water\ Intensity\ in\ 2016}$$

	Total Water Use/Production
Water Intensity in 2016	0.23
Water Intensity in 2017	0.22
Water Intensity in 2018	0.20
Total Improvement (2016-2017)	4.3%
Total Improvement (2016-2018)	13.0%
Annual Improvement in 2018 against 2016 baseline	8.7%
Annual Improvement in 2018 against 2017	9.1%

$$\boxed{\begin{aligned} &= Total\ Improvement\ in\ 2018 \\ &- Total\ Improvement\ in\ 2017 \end{aligned}}$$

- May be used if re-baselining every year
- Calculated similar to total improvement

Water Efficiency Measures

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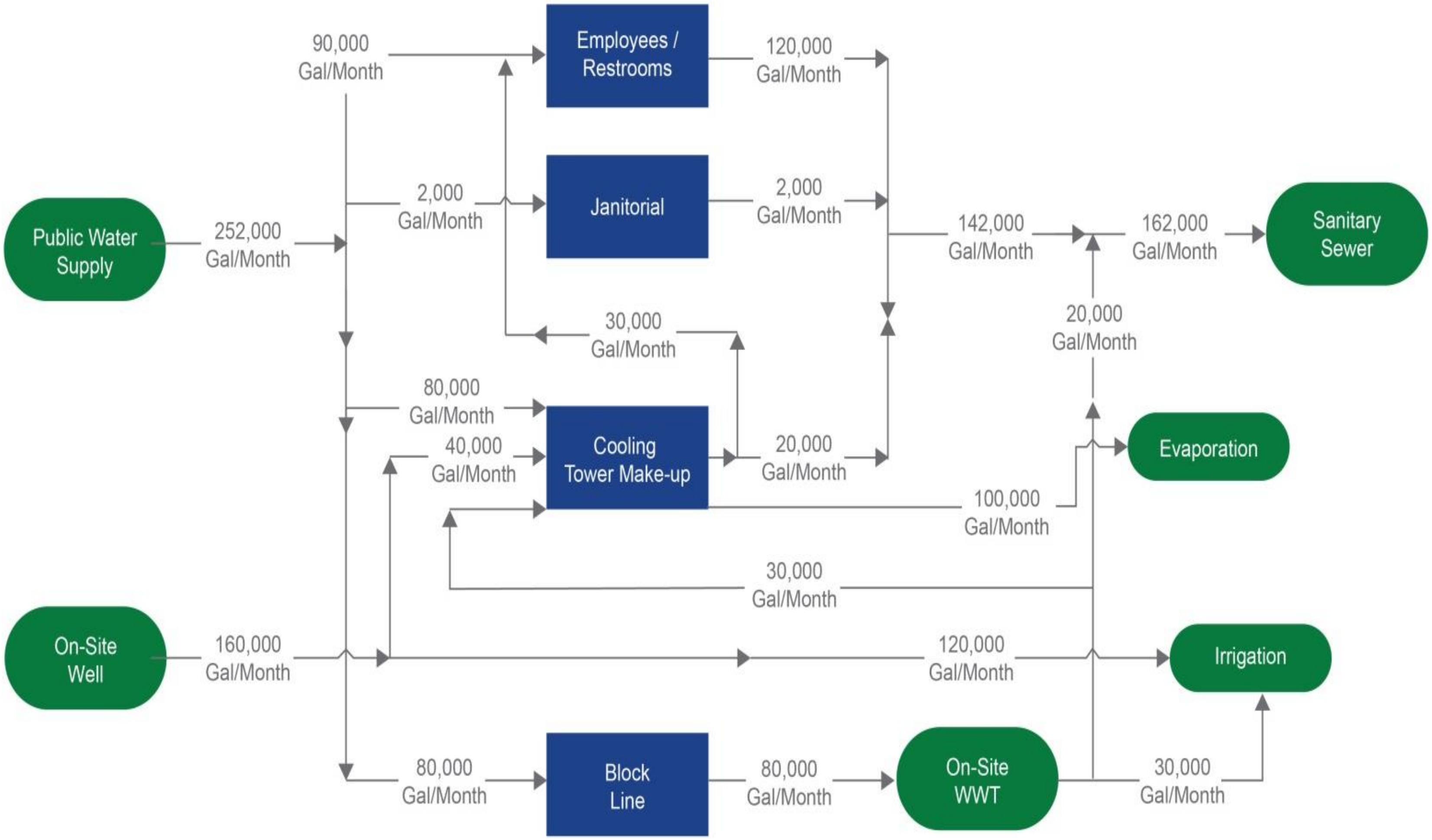
Identifying water saving projects

- Cummins, Saint-Gobain, and UTC develop water balances to identify projects
- Leak identification and repair a common water saving project
- Partners also demonstrated that advanced/novel actions are also doable
  - HARBEC: rainwater harvesting
  - Nissan: Water-reuse

Example of a water balance from Cummins



Data collection for conducting a balance

- Observed data collection methods
  - Meters for billed sources
  - Combination of estimation techniques and meters for other sources
- Most data collection occurred at the facility level
  - Example estimation techniques in previous slides
- Water use at the end-use level generally not tracked
  - Example equipment balances in later slides

Water use Category	Applicable to company (# of partners)	Able to track or estimate usage volume (# of partners)
Production and in-product use	5	3
Auxiliary processes (e.g., pollution control)	3	0
Cooling and heating (e.g., cooling towers and boilers)	6	2
Indoor domestic use (e.g., restrooms, kitchens, laundry)	6	1
Outdoor (e.g., landscape irrigation)	4	1

HARBEC: Rainwater harvesting

- 900,000 gallon rainwater retention pond offsetting cooling loads and tower make-up water
- 145,000 gallons/month reduction in purchased water
- 17,000 kWh/month in energy savings from reduction in cooling pump and fan loads from 50 hp to 6 hp
- Motivated by increasing fire insurance premiums
- Simple financials:
  - Saved $50,000 in avoided insurance costs
  - Saved $3,000 in water cost
  - Energy cost savings
  - $250,000 implementation cost

Nissan - Water Reuse at Smyrna, TN plant

- Phosphate removal using once through rinsing
  - Water treated onsite (consumes energy) and discharged to sewer
  - Make-up water from municipal and RO water (consumes energy)
- Water filtration system installed
- Saved 50 million gallons of water in 2015 compared to 2014
- Simple financials:
  - $320,000 water cost savings
  - $640,000 implementation cost

Examples of projects implemented by partners

Type of Measure	Examples of Type of Measure
Leaks	▸ Leak detection and correction
Monitoring and controls	▸ Adjustment on control valves to improve water efficiency ▸ Automate controls on continuous flow streams ▸ Change faucets to auto type faucets ▸ Install low flow fixtures ▸ Install thermal proportioning valves ▸ Install automatic shutoff valves ▸ Implement procedures to monitor and adjust the flow on water cooled equipment ▸ Monitor water quantity and quality ▸ Monitor cooling tower cycle of concentration
Recycle/reuse	▸ Eliminate once through cooling, including installing closed loop chillers ▸ Recycle non-contact cooling water ▸ Modify existing equipment to eliminate non-contact water cooling ▸ Clean and recirculate treated contact water ▸ Install semi-closed loop water system ▸ Use recycled water for process water ▸ Reuse process water, including capturing formerly discharged cooling tower wastewater for use in a recirculating chilled process water loop system.

Examples of projects implemented by partners cont.

Type of Measure	Examples of Type of Measure
Substitute water	▸ Replace water with other coolants (i.e. air and antifreeze in a closed loop circuit) ▸ Replace water cooled compressors with air cooled compressors ▸ Replace water cooled chilled water system with air cooled system ▸ Install air cooled systems in place of non-contact cooling water ▸ Replace water cooled vacuum pumps with air cooled units ▸ Install waterless urinals throughout the facility
Training	▸ Increase water usage awareness throughout the facility ▸ Train operators in the most water efficient procedures
Water storage	▸ Design of rinse tank overflow systems ▸ Install rain water harvesting system ▸ Capture and store water during facility shutdowns for future use, instead of discharging to sewers

System Dives - Pumping Systems

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Saving water = saving energy

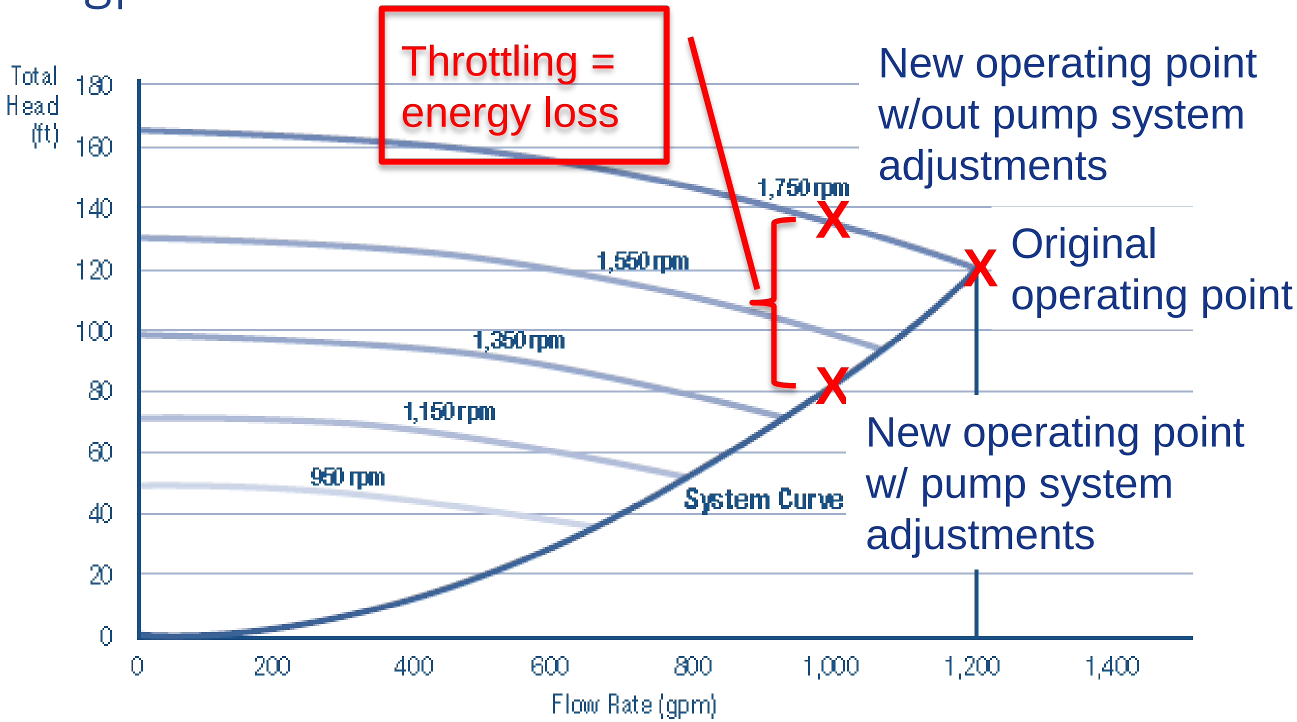
- Water saving measures may reduce the amount of energy required to pump water
- To first approximation, a reduction in flow leads to a cubic reduction in brake horsepower for centrifugal pumps

$$\frac{BHP_2}{BHP_1} \approx \left(\frac{Flow_2}{Flow_1}\right)^3$$

- To realize savings, adjustments to the pump system must be made

Centrifugal pump system operating at various flow rates

Example: water requirements reduced from 1,200 gpm to 1,000 gpm



$$Energy\ Demand = Flow\ x\ head$$

Background image taken from USDOE. 2007. Pumping Systems Tip Sheet # 11.

Options for pump system adjustment

- If the water flow is permanently reduced:
  - Impeller trimming will operate the pump at the desired speed and take advantage of the affinity laws
  - If required water flow increases, cannot “undo”
  - If the water flow is reduced dramatically, consider installing new pump
- If the water flow is reduced but still variable:
  - Consider installing a variable frequency drive (VFD) if the system curve is not dominated by high static head
  - Make sure to take into account losses across VFD and motor when considering economics

Pump system resources from DOE

Go to: https://energy.gov/eere/amo/pump-systems

- Software Tools: Pumping System Assessment Tool
  - Establishes system efficiency
  - Quantifies potential energy savings
  - Examines different operating scenarios
  - Identifies poorly performing pumps
- Literature: Sourcebook, tip sheets, case studies
- Training: both online and onsite by an expert

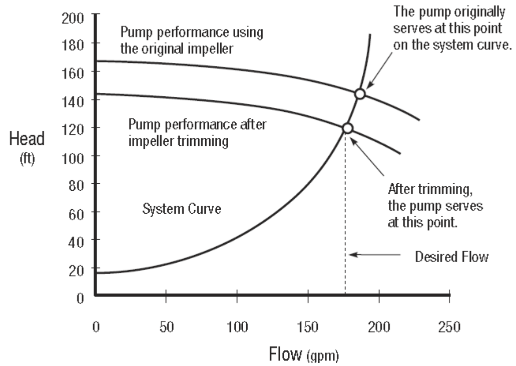


Image on left taken from USDOE. 2006. Improving Pumping System Performance: A Sourcebook for Industry, 2nd Edition, on right taken from USDOE. 2010. Pumping System Assessment Tool Factsheet.

System Dives - Cooling Towers

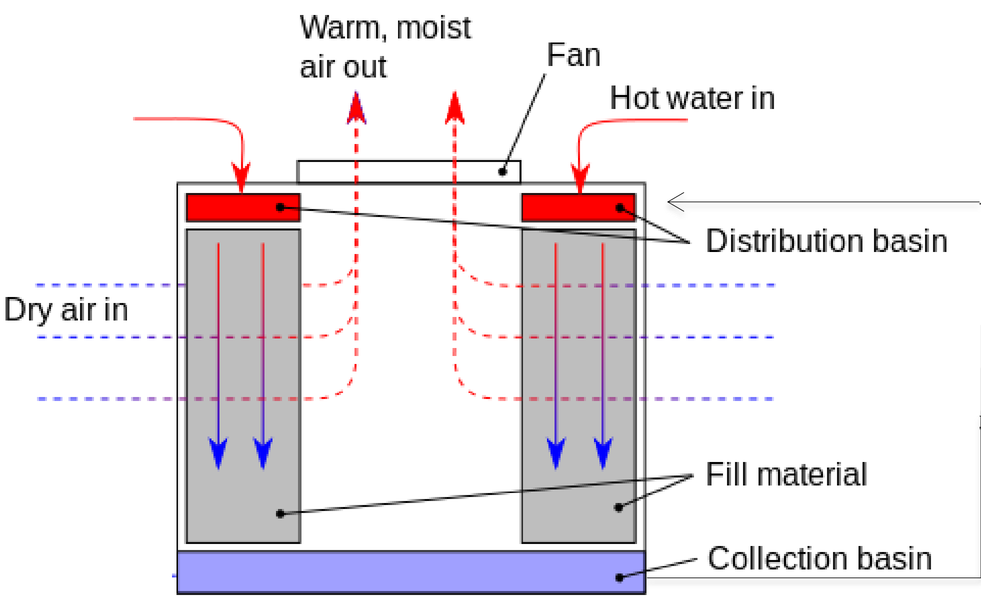
U.S. DEPARTMENT OF
ENERGY

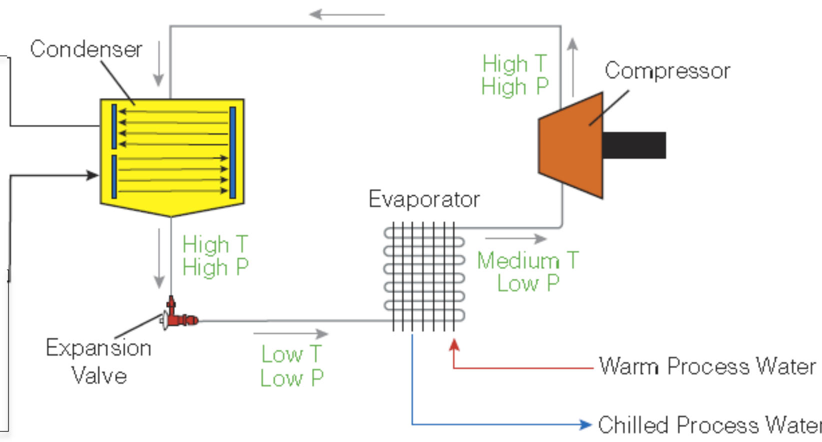
Cooling Towers

- Significantly reduces water use and consumption over once-through-cooling
- Common equipment for using water to cool processes and facilities
- Works on principle of evaporation, leading to water *consumption*
- Operations often left to "feel" - many opportunities for water and energy savings

Image taken from Muller, M et al. 2013. Optimize Energy Use in Industrial Cooling Systems. Chemical Engineering Progress.

Cooling tower operation





Principle of operation (cross flow towers): warm process/facility water is trickled down the cooling tower "fill" where outside air is drawn over the water and cools its through evaporation

Image on left taken from Wikipedia, "Cooling Tower", accessed on April 28, 2017, on right from Muller, M et al. 2013. Optimize Energy Use in Industrial Cooling Systems. Chemical Engineering Progress.

How and how much water is used

Evaporation

- 3 gpm of water for 1 ton* of cooling
- 1.8 gpm of consumptive water per ton of cooling

\+ Drift

- 0.05% - 2% of water flow rate
- Minimal water use

\+ Blowdown

- Variable depending on cycles of concentration

Total Water Use

- Is replenished through make-up water

*A ton of cooling for cooling towers is 15,000 Btu/hr rather than the usual 12,000 Btu/hr

Example of water use in a 100 ton cooling tower

CYCLES	EVAPORATION (gph)	BLOWDOWN (gph)	MAKE-UP (gph)
Once Through	0	18,000	18,000
1.2	180	900	1,080
1.5	180	360	540
2.0	180	180	360
2.5	180	120	300
3	180	90	270
4	180	60	240
5	180	45	225
6	180	36	216
7	180	30	210
8	180	26	206
10	180	20	200

If operating ½ the year, equates to 1.57 million gallons per year

Water reduction options

- Reduce cooling requirements
  - Remember: 1.8 gpm for every $\Delta 10^0$F across the condenser
  - Will also save on chiller energy requirements: 2% reduction in energy for every 1^0F decrease in condenser temperature
  - Review cooling requirements, ensure heat transfer surfaces and channels are maintained
- Increase cycles of concentration (see next slide)
- Ensure air flows through fill
  - Replace broken/rotten fill
  - Close sump doors
- Air-cooled towers
  - More expensive
  - Less energy efficient
  - No water use

Cycles of Concentration

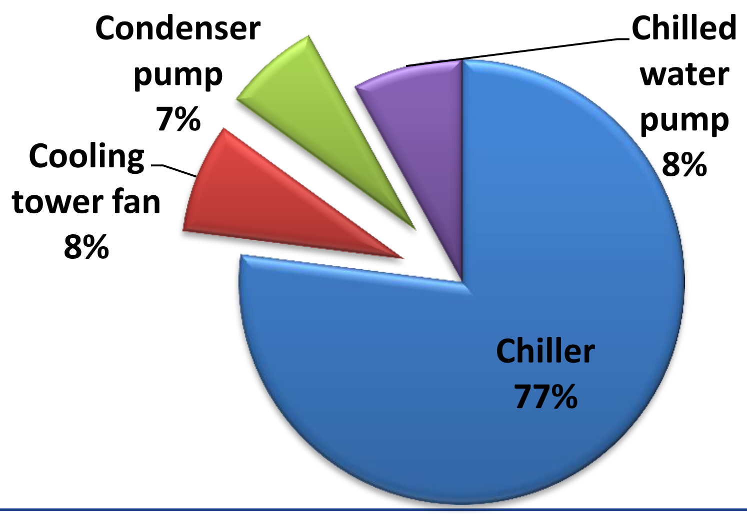
Initial Concentration Ratio (CR_i) \ New Concentration Ratio (CR_f)	2	2.5	3	3.5	4	5	6	7	8	9	10
1.5	33%	44%	50%	53%	56%	58%	60%	61%	62%	63%	64%
2	--	17%	25%	30%	33%	38%	40%	42%	43%	44%	45%
2.5	--	--	10%	16%	20%	25%	28%	30%	31%	33%	34%
3	--	--	--	7%	11%	17%	20%	22%	24%	25%	26%
3.5	--	--	--	--	5%	11%	14%	17%	18%	20%	21%
4	--	--	--	--	--	6%	10%	13%	14%	16%	17%
5	--	--	--	--	--	--	4%	7%	9%	10%	11%
6	--	--	--	--	--	--	--	3%	5%	6%	7%

- Consider installing conductivity meters to the sump and automating blowdown
- Consider adding acid treatment to minimize scale build up and allow for operation at higher cycles of concentration

Table taken from North Carolina Department of Environment and Natural Resources. 2009. Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities.

Energy use in cooling towers

- Two energy uses:
  - Cooling tower fan – draws ambient air over fill
  - Condenser water pump – transports hot water from condenser to the cooling tower fill (sold separately from cooling tower)
- Energy use breakdown for 500 ton chiller operating at ASHRAE minimum standard efficiencies– 15% for cooling tower*



*Morrison, F. 2014. Saving Energy with Cooling Towers. ASHRAE Journal.

Energy saving opportunities (for existing towers)

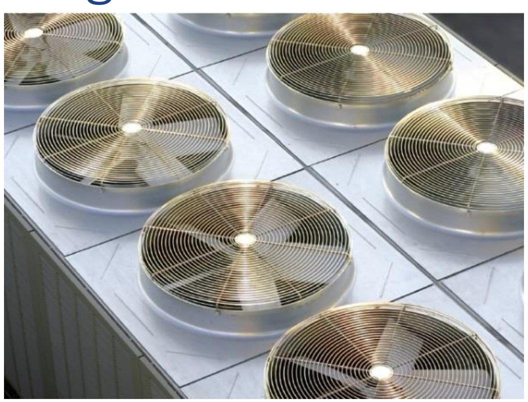
- Fan and pump best practices:
  - Regular maintenance (belts, lubrication, packing)
  - Repair or replace motors with higher efficiency options upon failure
  - Operate fans and pump at best efficiency points
- VFDs on cooling tower fans
  - If operating multiple towers, better to operate all at <100% load with a VFD rather than on/off sequence
  - Example: Running 4 fans at 56% load, rather than 2 fans at 100% and other 2 off, will achieve the same exiting water temperature but consume 60% less energy (if fans are fitted with VFDs)*

*Morrison, F. 2014. Saving Energy with Cooling Towers. ASHRAE Journal.

Fan system resources from DOE

Go to: https://energy.gov/eere/amo/fan-systems

- Software Tools: Fan System Assessment Tool
  - Calculates fan system energy use
  - Determines system efficiency
  - Quantifies savings from optimization
- Literature: Fan System Sourcebook, Case Studies
- Training: both online and onsite by experts available



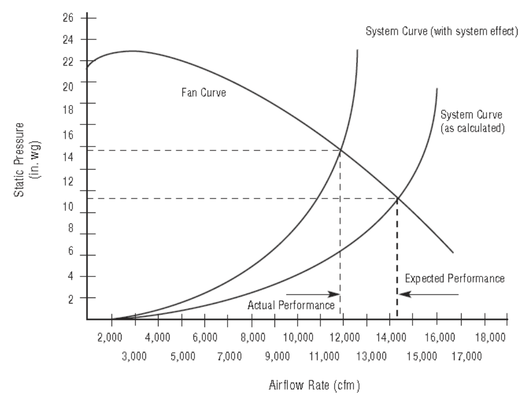


Image on left taken from USDOE. 2010. The Fan System Assessment Tool Fact Sheet, right taken from USDOE. 2003. Improving Fan System Performance: A Sourcebook for Industry

System Dives - Steam

Steam Systems

- Large energy and water use at U.S. manufacturing facilities
- 31% of onsite energy use*
- 11% of onsite water use**

*DOE EIA MECS 2010
**Walker, et. 2013.
Image taken from iStock/11893854

Steam system operation

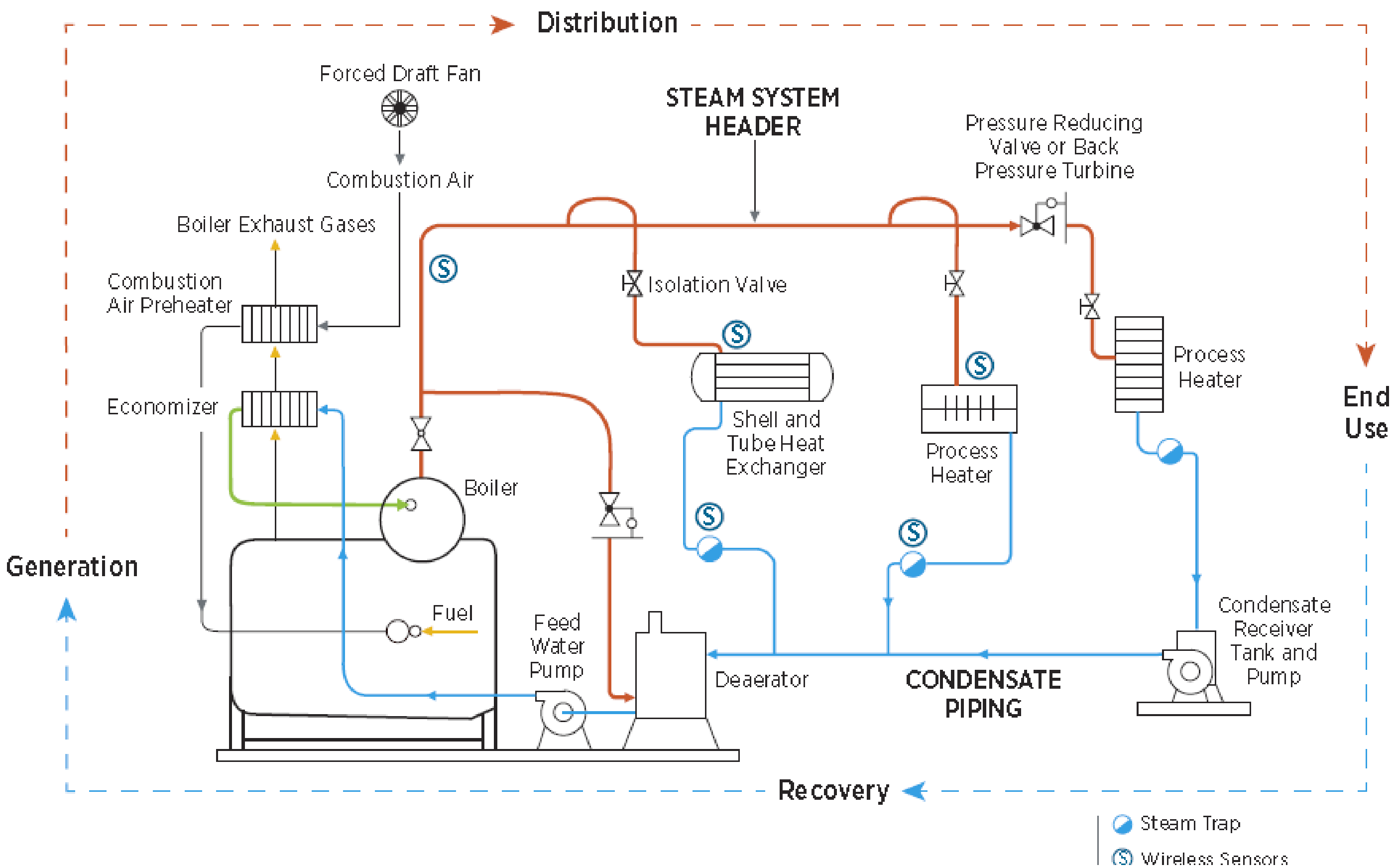


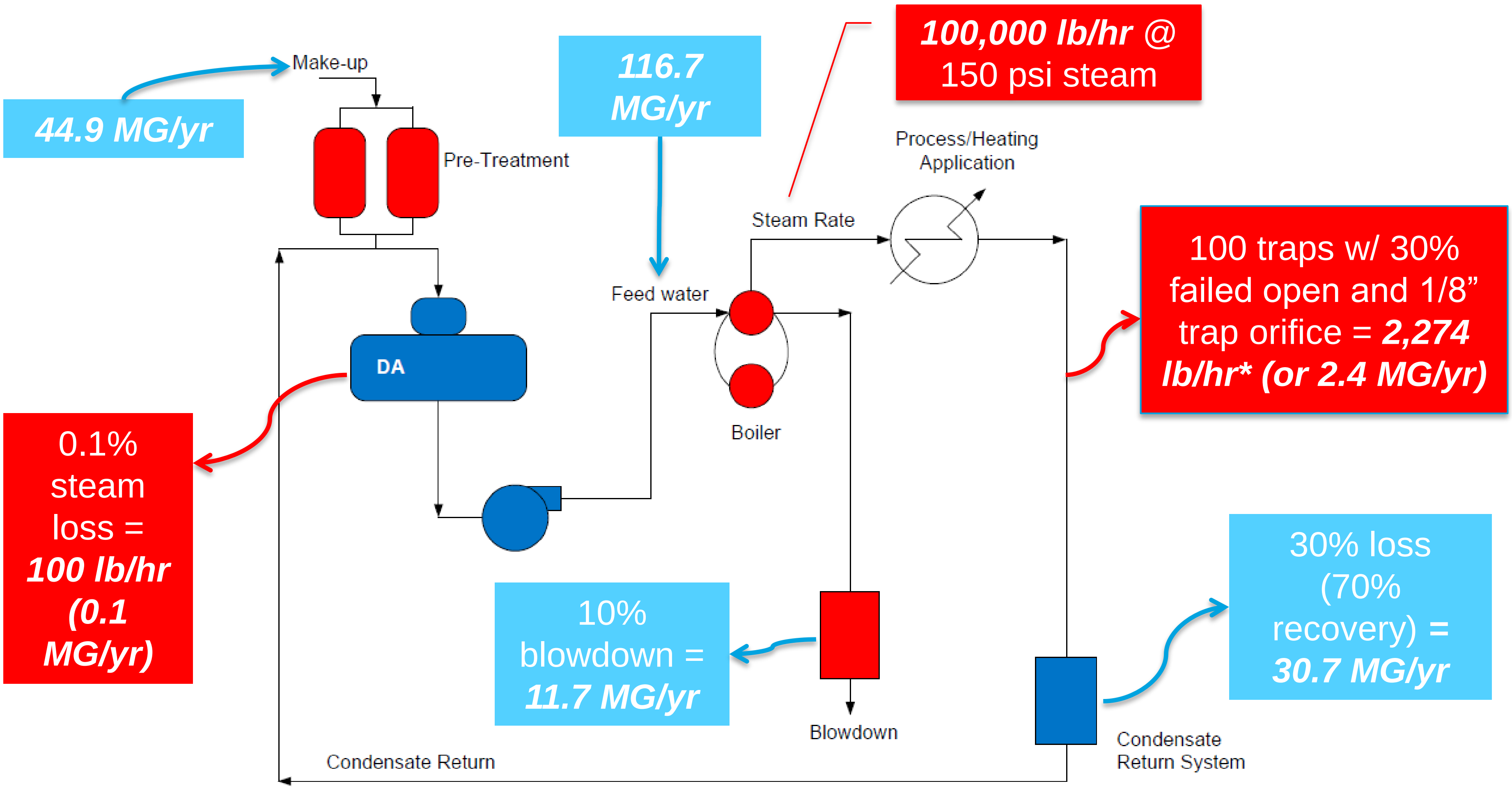
Image taken from USDOE. 2012. Improving Steam System Performance: A Sourcebook for Industry, 2nd Edition

How and how much water is used

Blowdown	→	• Typically 4 – 8% of boiler feedwater flow rate • Can be as high as 10%
+ Condensate loss	→	• Not all can be returned; ~10% lost as flash steam • Goal of 75-80% recovery is reasonable
+ Steam Leaks	→	• From pipes, broken traps, or other unintended loss • 10-30% broken traps
+ Deaerator	→	• 0.1 - 0.2% of feedwater flow
Make-Up Water		

*Feedwater Flow Rate = (Steam Mass Flow Rate / ρ_{water}) + Make-Up Water

Example of water use in a steam system



*See Steam Tip Sheet # 1: Inspect and Repair Steam Traps

Background image taken from Boyd, BK. 2010. Guidelines for Estimating Unmetered Industrial Water Use.

Increasing condensate recovery from 70% → 80%

- Water: Reduces amount of make-up water required
  - In example, saves ~10 MG and ~$50,000 in water and sewer charges annually
- Energy: Rather than heating city/cold water (~60^{0}F) to saturated steam, facility will heat hot water (358^{0}F in example)
  - In example case, saves ~31,000 MMBtu and ~$119,000 in fuel costs annually
- Chemicals: Reduces amount of chemical treatment required for make-up water
- How to do it: Install insulated piping, tank, and treatment

Assumptions:
Natural gas fired boiler operating 80% efficiency and $3.78/MMBtu natural gas cost
Water and sewer costs of $5/1000 gallons

Reducing blowdown from 10% → 5%

- Water: Reduces make-up water to compensate for blowdown loss
  - In example case, saves ~6 MG and ~$31,000 in water and sewer charges annually
- Energy: Water lost is blowdown is very hot (358^{0}F in example) and has to be made up with cold water (~60^{0}F)
  - In example case, saves ~19,000 MMBtu and ~$73,000 annually
- How to do it: Automate blowdown by controlling blowdown valve through measurement of conductivity.

Assumptions:
Natural gas fired boiler operating 80% efficiency and $3.78/MMBtu natural gas cost
Water and sewer costs of $5/1000 gallons

Fixing steam traps/leaks

- Steam is lost through traps that are broken "open"
- Water: reduces make-up water needed to compensate for steam lost through traps
  - Reducing to 10% broken trap in example case saves ~1.6 MG and ~$8,000 in water and sewer charges annually
- Energy: reduces amount of steam that has to be re-generated to compensate for steam losses
  - Reducing to 10% broken traps in example case saves ~20,000 MMBtu and ~$75,000 annually
- How to do it: Implement a steam trap inspection program (using visual, temperature, or sound inspection) and fix traps as they break

Assumptions:
Natural gas fired boiler operating 80% efficiency and $3.78/MMBtu natural gas cost
Water and sewer costs of $5/1000 gallons

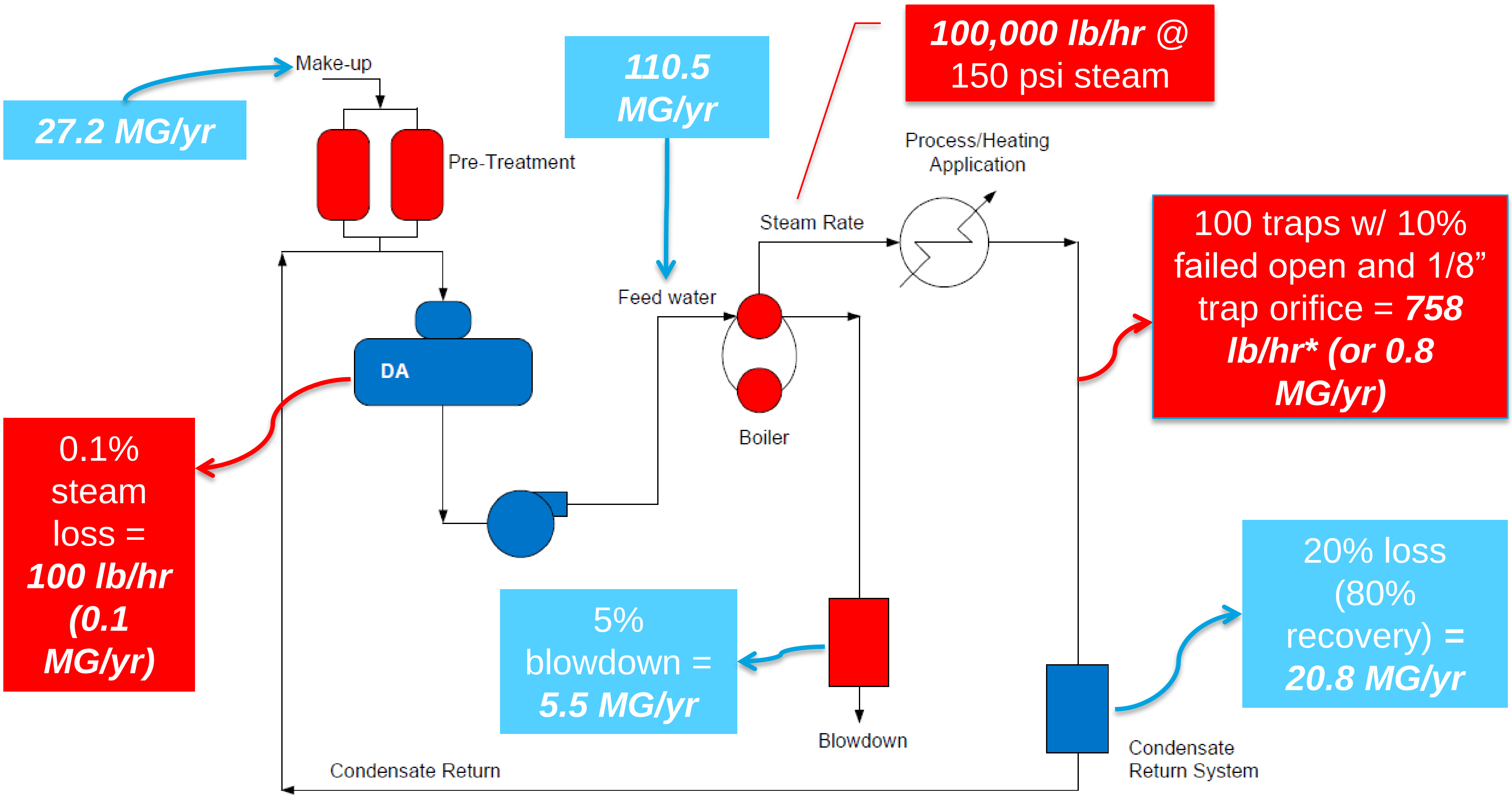
Total annual water and energy savings in example

Over ***$356,000*** in annual water and energy savings from these three measures

Measure	Energy savings	Energy cost savings	Water savings	Water/sewer cost savings
Return more condensate	31,000 MMBtu	$119,000	10 MG	$50,000
Reduce blowdown	19,000 MMBtu	$73,000	6 MG	$31,000
Fix broken steam traps	20,000 MMBtu	$75,000	1.6 MG	$8,000
Total savings	***70,000 MMBtu***	***$267,000***	***17.6 MG***	***$89,000***

40% reduction in water use!

Example of water use in a steam system after water/energy saving actions



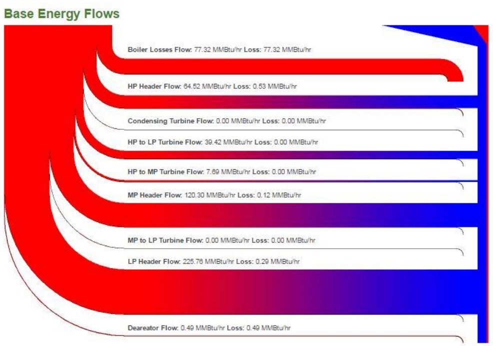
*See Steam Tip Sheet # 1: Inspect and Repair Steam Traps

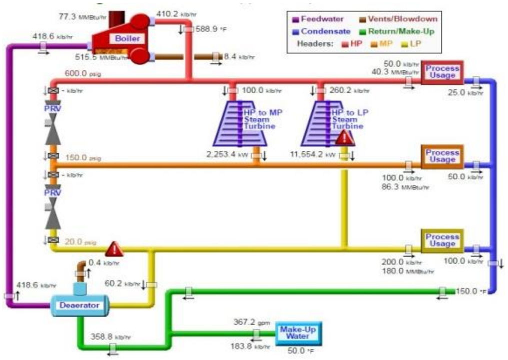
Background image taken from Boyd, BK. 2010. Guidelines for Estimating Unmetered Industrial Water Use

Steam system resources from DOE

Go to: https://energy.gov/eere/amo/steam-systems

- Software Tools: Steam System Modeler
  - Models your steam system
  - Alter model and compare to identify energy saving opportunities
  - Provides interactive heat balance and steam properties
- Literature: Sourcebook, tip sheets, case studies, technical publications
- Training: List of qualified specialists

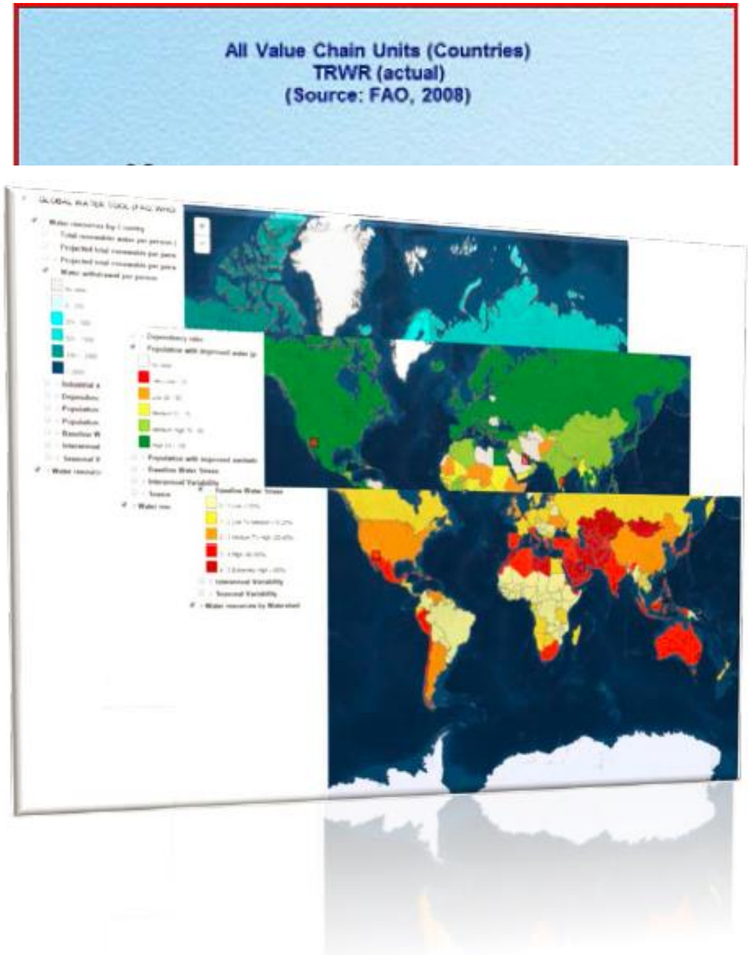




Other Tools and Resources

Global Water Tool

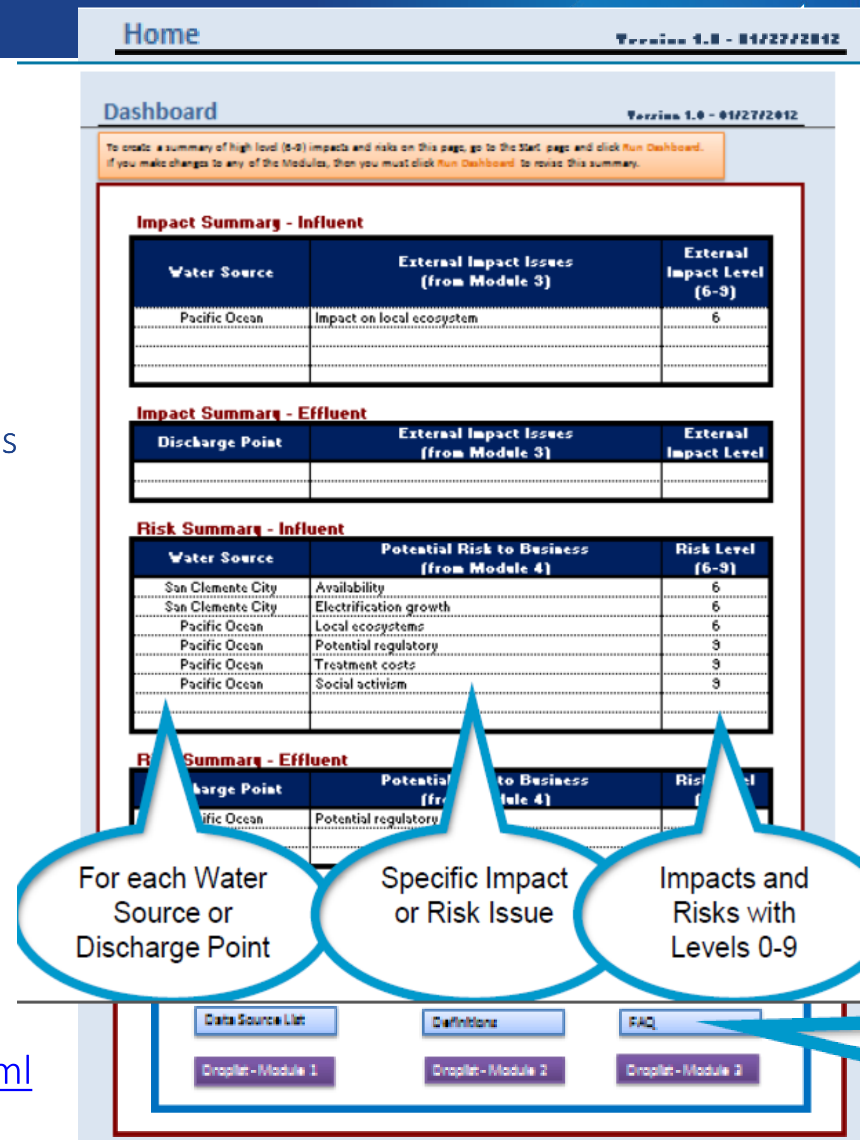
- By WBCSD (World Business Council for Sustainable Dev.)
- Target: Portfolio level
- Purpose:
  - Understanding needs and potential water availability and quality risks at a global level by allowing facilities to assess their own water use info relative to country and watershed info.
- Format: online, 10 steps
- Compatible with GEMI's LWT to build water management plans at a specific site or operation



Available at: http://old.wbcsd.org/work-program/sector-projects/water/global-water-tool.aspx

Local Water Tool™ (LWT)

- By GEMI & WBSCD (40+ companies)
- Target: Facility level
- Purpose:
  - Help companies assess impacts, risks, opportunities and manage water-related issues at specific sites
- Format: Excel®, 6 modules:
  1) Site data
  2) Local external conditions
  3) External impacts assessment
  4) Risk assessment
  5) Management plan
  6) Reporting and summary dashboard



Available at: http://gemi.org/localwatertool/about.html

Collecting the Drops: A Water Sustainability Planner

- By GEMI (Global Environmental Management Initiative)
- Target: Facility level
- Purpose:
  - A detailed and comprehensive water sustainability-planning tool that can be used by a company to establish baseline performance, assess opportunities, set goals and evaluate progress against objectives
- Format: online, 3 modules:
  1) Facility Water Use and Impact Assess. Program (water flow and water balance)
  2) Water Mgmt. Risk Assessment Questionnaire
  3) Case Examples and Links

Available at: http://waterplanner.gemi.org/index.htm

Table 4. Sample of Questionnaire Inputs

Questionnaire:
Watershed 2 of 7

1. Enter the name of the watershed that the facility relies on for its water supply. This would be the watershed that the water is withdrawn from by the supplier or through private withdrawals from groundwater or surface water.
Type answer here:

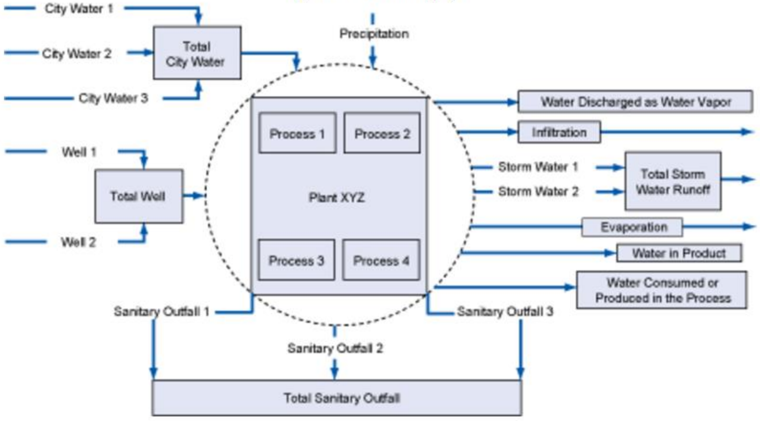
Aquifer

2. There are several ways that water is withdrawn from the watershed. Water is withdrawn from surface water (rivers and streams) from groundwater through production wells or through the collection and use of precipitation. Please enter the sources of water withdrawn from the watershed by the supplier or privately owned water supply system (surface water, groundwater, precipitation).
Type answer here:

Groundwater

3. What is the average annual rainfall at your facility? Using your internet browser, type in "average annual rainfall" for your facility location. Another link that has reference information is http://www.worldclimate.com.

Figure 1. Sample Water Flow Diagram
(Click to enlarge)



Tools / Resources by User

Facility Manager

- Site Water Risk Assessment
  - GEMI Collecting the Drops: A Water Sustainability Planner
  - GEMI® Local Water Tool™
- Implement Water Program
  - NC DENR Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities
- Site Water Audit
  - EDF Cooling Tower Efficiency Guide Property Managers
  - EPA Lean & Water Toolkit

Corporate Sustainability Manager

- Global Water Risk Awareness
  - WBCSD Global Water Tool
  - WRI Aqueduct Tool
- Portfolio Assessment
  - EDF-GEMI WaterMAPP: Water Scorecard
- Financial Business Case
  - Water Risk Monetizer
  - EDF-GEMI WaterMAPP: Water Efficiency Calculator (cooling tower)

For more Information

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BetterPlants@ee.doe.gov

Better Buildings, Better Plants:
http://eere.energy.gov/betterplants

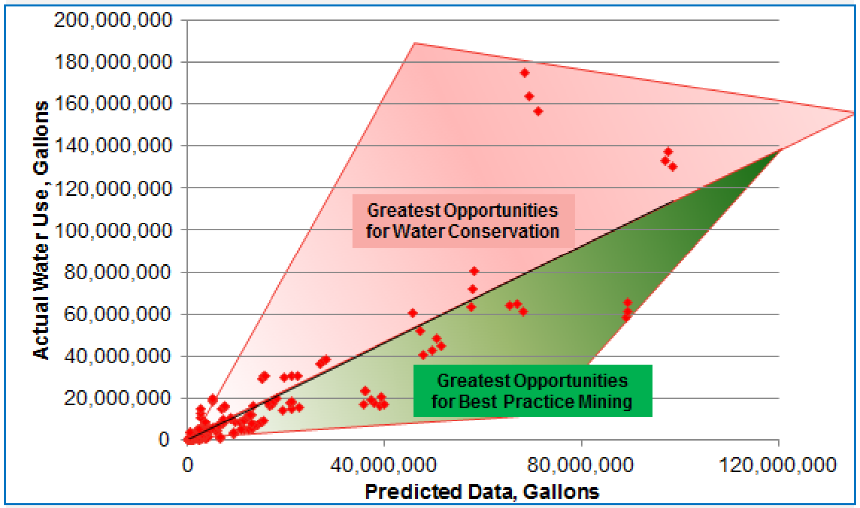
Better Buildings Challenge:
http://betterbuildingssolutioncenter.energy.gov/

Back Up Slides

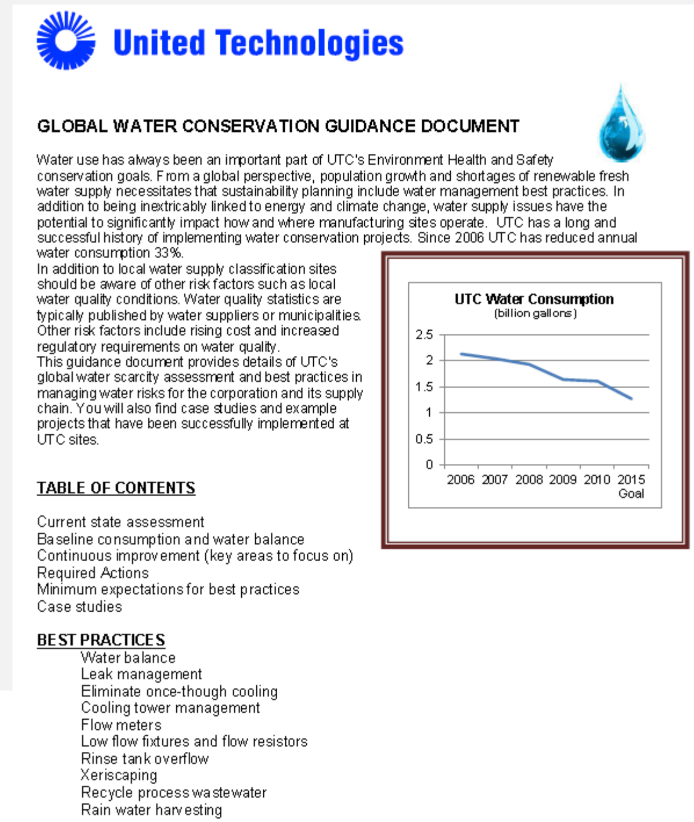
U.S. DEPARTMENT OF ENERGY

Prioritizing facilities for implementation

Cummins water performance index



UTC Global Water Conservation Guidance Document



United Technologies

GLOBAL WATER CONSERVATION GUIDANCE DOCUMENT

Water use has always been an important part of UTC's Environment Health and Safety conservation goals. From a global perspective, population growth and shortages of renewable fresh water supply necessitates that sustainability planning include water management best practices. In addition to being inextricably linked to energy and climate change, water supply issues have the potential to significantly impact how and where manufacturing sites operate. UTC has a long and successful history of implementing water conservation projects. Since 2006 UTC has reduced annual water consumption 33%.

In addition to local water supply classification sites should be aware of other risk factors such as local water quality conditions. Water quality statistics are typically published by water suppliers or municipalities. Other risk factors include rising cost and increased regulatory requirements on water quality.

This guidance document provides details of UTC's global water scarcity assessment and best practices in managing water risks for the corporation and its supply chain. You will also find case studies and example projects that have been successfully implemented at UTC sites.

UTC Water Consumption
(billion gallons)
2.5
2
1.5
1
0.5
0
2006 2007 2008 2009 2010 2015 Goal

TABLE OF CONTENTS

Current state assessment
Baseline consumption and water balance
Continuous improvement (key areas to focus on)
Required Actions
Minimum expectations for best practices
Case studies

BEST PRACTICES
- Water balance
- Leak management
- Eliminate once-though cooling
- Cooling tower management
- Flow meters
- Low flow fixtures and flow resistors
- Rinse tank overflow
- Xeriscaping
- Recycle process wastewater
- Rain water harvesting

Selecting water sources

- Water sources included by partners listed below

Water source	Applicable source (# of partners)
Public water supply	7
Ground water	3
Surface water	3
Rain water	2
Recycled/reuse water	0
Non-fresh water intake	1

- Other considerations when selecting sources:
  - Consumption versus use
  - Discharge water quality

Water costs

- Partners average water costs to water and sewer authorities were $5.78/1000 gallons
  - Ranged from $4.00 - $6.71/1000 gallons
- 5 partners reported water costs were negligible to less than 1% of overall production costs
- 1-2 year payback requirements
  - GM allows 3 year payback for projects at new facilities
- Projects that only save water are difficult to justify financially

Sampling of industrial water rates

	Water Supply		Sewer	
City, State	Water Authority	Range of water supply volume rate per 1000 gallons⁺	Sewer Authority	Example⁺⁺ sewer volume rate per 1000 gallons
Asheville, NC	City of Asheville	$2.42 - $4.44	Metropolitan Sewerage District	$4.94
Hartford, CT	Metropolitan District Hartford, CT	$3.56	Metropolitan District Hartford CT	$3.82
Kansas City, MO	Kansas City Water Services	$3.68 - $6.35	Kansas City Water Services	$9.49
Los Angeles, CA	LA Department of Water and Power	$6.36 - $8.58	LA Sanitation	$5.66
Milwaukee, WI	Milwaukee Water Works	$1.54 - $2.66	Local Charge + Milwaukee Metro Sewerage District	$2.73⁺⁺⁺
San Antonio, TX	San Antonio Water System	$1.97 - $3.45	San Antonio Water System	-
Virginia Beach, VA	City of Virginia Beach	$4.41	Hampton Regional Sewerage District	$5.52

Sources: City of Asheville, MDC, MSD, Kansas City Water Services, LADWP, LADS, MWS, Cudahy Wisconsin, MMSD, San Antonio Water System, City of Virginia Beach, HRSD

⁺Actual rate depends on usage volume. Additional base charges and seasonal charges not included

⁺⁺Does not include charges for higher concentration discharges and connection charges

⁺⁺⁺Cudahy district local charged used in example charge

Strategies employed by Pilot partners for making the business case

- Low or no cost actions (e.g. leak repair)
- Water savings as an ancillary benefit
  - Ford "3-Wet Paint" process reduced CO_2, VOCs, and water
- Connect water and sustainability programs
- Consider avoided risk, water availability concerns, local regulations when considering projects
- Use the "True Cost" of water: water volume, energy, chemicals, business risk, maintenance of equipment
  - Cummins calculated true cost to be 3-5x billed water costs
  - 10-12x for high energy/water intensive operations

Benefits of tracking water intensity

- Tracks progress towards target
- Critical to water management program
- Can be significant component of environmental footprint
- Provides insight into effectiveness of water saving actions
- Enables broader communication of efforts